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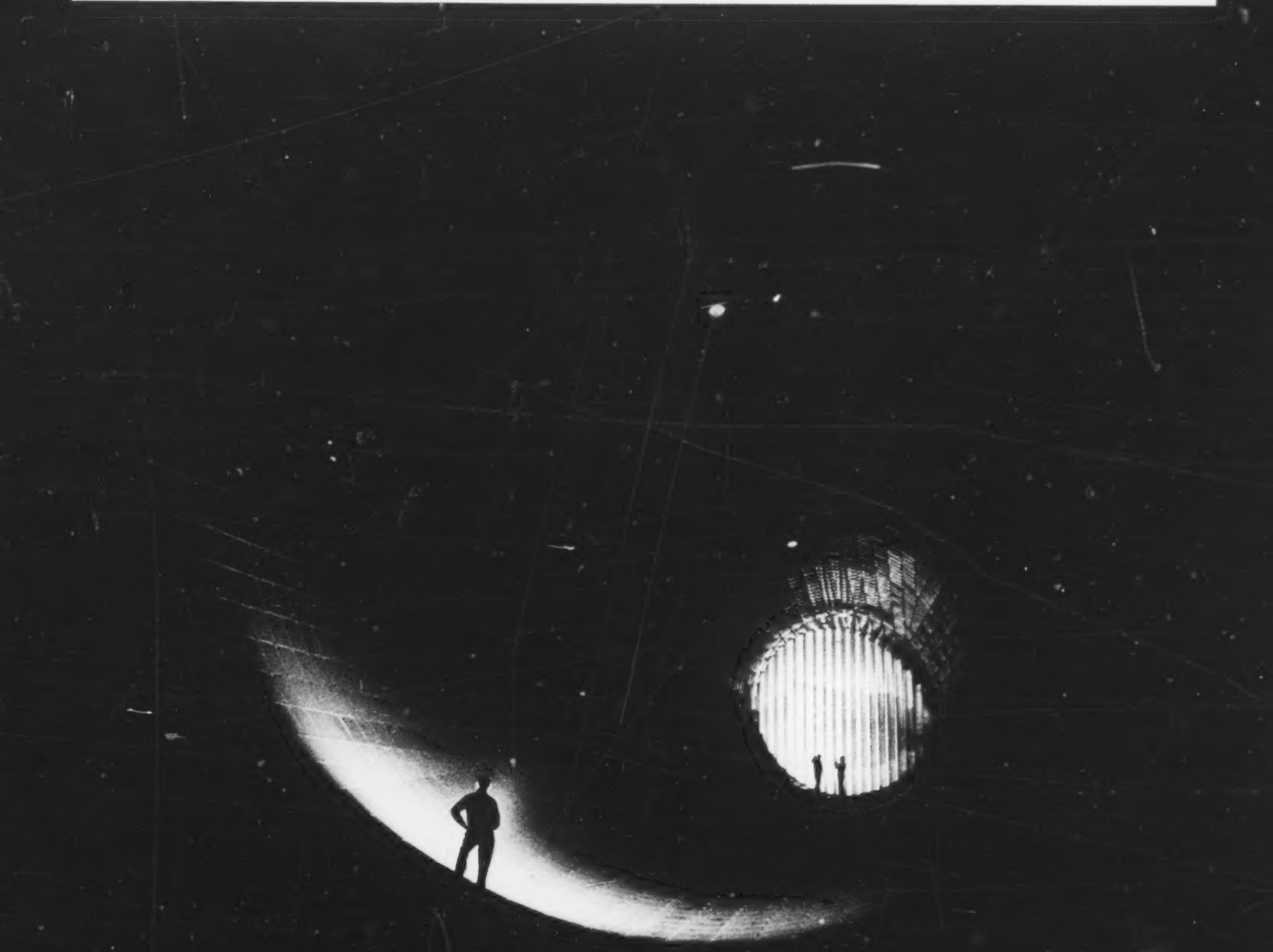

- Arnold Engineering Development Center
- The Outlook For Space Commercialization

Notable views of notable people on aerospace matters...

aerospace perspectives

Leon Wieseltier, *literary editor of The New Republic and author of Nuclear War, Nuclear Peace, writing in the Los Angeles Times:*

"The nuclear debate of recent years has consisted of a contest between idealism and realism (deterrence) . . . It is emotionally very difficult to make do with the idea that the greatest threat to human history should be met with concepts of management—which is what the idea of deterrence asks. And yet idealism is not the most responsible approach to the nuclear danger. Indeed, it is the very magnitude of the danger that makes idealism the least responsible method of anti-nuclear thought and anti-nuclear action . . .

"I propose a division of intellectual and political labor. Let those who insist that there must be an idea that will end the nuclear era keep searching for the idea. They do not deserve to be scorned. But neither do those who insist that in the interim the danger must also be managed; and frequently they are.

"As Irving Howe has observed, there is the politics of the near and the politics of the far. Nuclear politics must allow for both. After all, when it is the destruction of the world that we are talking about, it is an honorable thing to trouble about the here and now. Somebody has to."

Robert MacFarlane, *Assistant to the President for National Security Affairs, speaking to the Commonwealth Club in San Francisco, California:*

"The result of U.S. weapons development during the '60s and '70s has been one of reducing unilaterally the size and number of our weapons. Did you know, for example, that the number of nuclear weapons in our arsenal today is 25 percent lower than 17 years ago and the megatonnage of those weapons is 75 percent lower than in the mid-1960s? Did you know that in 1979 we and our allies unilaterally removed 1,000 warheads from Europe? Did you know that last year President Reagan and our NATO allies agreed to the withdrawal of 1,400 more? These unilateral reductions were not the result of arms negotiation. The other side made no corresponding reductions. So Point Number One is that even without an arms control agreement your government has reduced arms . . .

"Since the SALT I talks started in 1969, the Soviets have added over 7,000 nuclear weapons to their arsenal; since SALT II was signed, over 3,800 . . . Point Number Two, therefore, is that arms control agreements do not necessarily reduce the level of arms . . . Since the signing of the SALT I agreements in 1972, we have built only two strategic systems while the Soviets have built 31. Point Number Three is that agreements have not induced a Soviet attitude of restraint. Point Number Four concerns compliance. Soviet violations of agreements . . . undercut any argument that agreements with the Soviets are grounds for greater confidence in our safety.

"What should we conclude from this history—that arms control is hopeless? Surely not. There have been times when we have succeeded. They have come when the Soviets have had to accept that, unless they come to terms, we are prepared to build a better system than they."

Verne Orr, *Secretary of the Air Force, in an address to the Air Force Association National Convention in Washington, D.C.:*

"Earnest people on the Hill, in both houses, have gotten behind a bill to create a 'peace' academy. In my opinion, they are too late. Exactly 182 years too late. We established the first peace academy in America on the banks of the Hudson at West Point, New York in 1802, and we call it the United States Military Academy. It and the other academies have just one purpose—peace.

"If we're going to raise a generation of negotiators and appeasers, a generation of Neville Chamberlains who think they can acquire peace through capitulation and without strength, I hope they will remember the words of Konrad Adenauer, who said that an infallible way of appeasing a tiger 'is to allow oneself to be devoured.'

"Major civic buildings usually have plaques. I hope the Academy of Peace, if there is one, places at one side of the entrance a plaque bearing the words of Lenin: 'It is inconceivable for the Soviet republic to exist alongside the imperialist states for any length of time. One or the other must triumph in the end. And before that end comes, there will have to be a series of frightful collisions between the Soviet republic and the bourgeois states.' "

James M. Beggs, *NASA Administrator, speaking at the NASA/National Academy of Sciences Symposium on Lunar Bases and Space Activities of the 21st Century in Washington, D.C.:*

"The Lunar Base Working Group meeting last April at Los Alamos (debated) the pros and cons of establishing a permanently manned base on the moon's surface (and) concluded that such a base should be adopted by NASA as a long-term goal for the 21st century.

"This goal has long been our vision, and still is. Even before Apollo, our studies concluded that such a base could serve a facility for scientific research, economic exploitation of the moon's resources and colonization of the moon . . .

"I believe it highly likely that before the first decade of the next century is out we will, indeed, return to the moon. We will do so not only to mine its oxygen-rich rocks and other resources, but to establish an outpost for further exploration and expansion of human activities in the solar system, in particular on Mars and the near-Earth asteroids."

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EDITOR • John F. Loosbrock

ASSOCIATE EDITORS • James J. Haggerty
Ellen Kelly
Jean Ross Howard

ART DIRECTOR • James J. Fisher

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On the cover: Vanes guide the airflow around corners in a 16-foot wind tunnel at Arnold Engineering Development Center *(see page 10).*

The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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NASA's SPACE COMMERCIALIZATION POLICY

This issue of *Aerospace* highlights a report on the outlook for space commercialization, concluding that there is great promise in exploiting space but it is too early to quantify the promise, due to a number of influencing factors whose outcome and impact are not now accurately measurable. Among those factors are acceptance of the space commercial potential by the financial community, corporate willingness to commit resources in high-risk ventures and, most importantly, government policies with respect to support of industries interested in commercializing space.

In November, NASA detailed the planned policy direction of the U.S. government with announcement of its Commercial Use of Space Policy, a follow-up to President Reagan's July statement on National Space Policy, in which he made the expansion of private investment and involvement in space a major objective.

Private investment in space, says the NASA policy statement, is expected "to yield important economic advantages; advance science and technology; help maintain U.S. space leadership; and enhance the nation's competitive position in international trade." The statement adds:

"Opportunities for benefiting the nation are significant. Commercial space endeavors offer the potential for new industries, new jobs, lower product costs and an improved balance of trade. Technological advances from commercial use of space could help conquer disease, produce computers faster and smarter than presently exist, develop metals lighter and stronger than any presently known, increase communications and information availability around the world and enhance our understanding of the environment and its resources."

The NASA document lists a series of initiatives to reduce the risks of doing business in space and thus encourage private investment.

To reduce *technical* risks, NASA will support research aimed at commercial applications, ease industry's access to NASA facilities, establish flight opportunities for commercial payloads, expand availability of technological information of commercial interest, and support development of new facilities for commercial uses of space.

To reduce *financial* risks, NASA will continue to offer reduced-rate space transportation for high-technology endeavors, assist in integrating commercial equipment with the Shuttle, provide seed-funding to stimulate space ventures and—under certain circumstances—buy commercial space products to provide an initial market.

The policy statement lists five guiding principles:

- The government should establish new links with the private sector, broadening its traditional association with the aerospace industry and the science community to include relationships with major non-aerospace firms, academia and the financial community.
- Regardless of the government's view of a project's feasibility, it should not impede private efforts to undertake space ventures.
- If the private sector can operate a space venture more efficiently than the government, such commercialization should be encouraged.
- The government should invest in high-leverage research and space facilities which encourage private investment. However, the government should not expend tax dollars for endeavors the private sector is willing to underwrite.
- When a major government contribution to a commercial endeavor is requested, two requirements must be met: the private sector must have significant capital at risk and there must be significant potential benefit to the nation.

This policy, says the statement, "will give new impetus and importance to traditional space efforts. At the same time, the policy will give private enterprises the extra push they need to get started with permanent, self-sustaining, tax revenue-producing establishments that will generate unique goods, well-paying jobs and new outlets for ingenuity and innovation in space and on the Earth. The rewards can be immense for our nation."

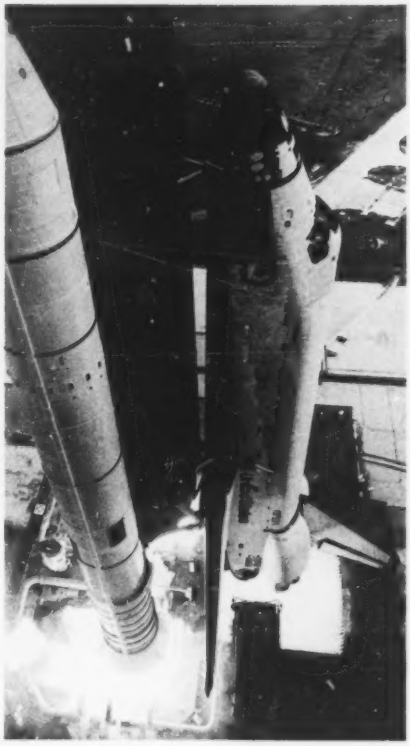
THE OUTLOOK FOR SPACE COMMERCIALIZATION

By JAMES J. HAGGERTY

October 1984 marked the 20th anniversary of the formation of the International Telecommunications Satellite Organization (Intelsat), the world's first commercial space enterprise. Which is by way of pointing out that space commercialization, widely heralded as an economically attractive prospect for the future, has in fact been a going and ever-expanding operation for two decades. Over that span, Intelsat has grown into an organization of 109 member nations whose 15 high-capacity satellites handle more than two-thirds of all international telephone communications and virtually all overseas television. There have also emerged a number of domestic and regional commercial satellite networks, along with separate systems for such specialized purposes as business data transmission and maritime communications. In addition to these operational entities, whose combined annual revenues approach $2 billion, there is a robust, innovative segment of the aerospace industry manufacturing satellites and ground equipment at the rate of about $1.5 billion a year.

Commercial space activities have so far been largely confined to communications—but not entirely. In recent years, there has been increasing commercial use of Landsat remotely-sensed data, for example by oil companies to identify areas that might contain petroleum deposits and by paper companies for more effective management of their forest land. Since the latter 1970s, McDonnell Douglas Corporation has been selling the world's first commercial space booster, an upper stage system that has launched 20 satellites. Since 1980, the French-dominated European space transport company—Arianespace—has been offering commercial launch services. Space manufacturing research has been under way for more than a decade and the first made-in-orbit product will soon be available for sale.

So space commercialization is not something new. What is new is the opportunity for vastly accelerated activity in all these areas, occasioned by a variety of factors. Projections indicate greatly expanded demand for space-based commercial communications services, which will in turn require increased production of both satellites and launch systems. A government decision to turn the Landsat system over to a commercial operator,



coupled with plans to improve collection and dissemination of information from the satellites, should spur greater commercial use of remotely-sensed data. The availability of the Space Shuttle, which makes possible Earth-returnable experiments in materials processing, is a major stimulant to corporate interest in space manufacturing; and the planned space station, which will house permanent facilities for manufacturing operations, represents an even greater stimulus. In addition, the government has stated a policy under which it would provide a broad range of economic and other incentives intended to reduce the risk of commercial space ventures and stimulate private sector investment.

That policy stemmed from recognition—by both the Administration and the Congress—that commercial space activity promises "immense benefits" and is essential to continued U.S. leadership in science, technology and trade. The governments of other free world industrialized nations are similarly aware of the potential and a number of them—notably France, West Germany and Japan—are aggressively pursuing it.

Will the immense benefits actually materialize? Our national impatience demands answers before the facts are available and there are many willing to supply them. Some see a space commercial boom of enormous dimension; others suggest it is a pleasant fantasy that will provide at best limited economic or societal benefit.

Such views are based more on intuition than fact. In the first place, it is difficult to forecast space commercialization in general terms, because there are several different areas of commercialization and each has a different set of problems and prospects. Additionally, there are many influencing factors that affect each of these areas, factors whose outcome and impact are not now accurately measurable. They include such considerations as the extent to which governments will back their spacebound industries, not only with policies but with direct support and financial incentives; greater awareness and acceptance of the space potential by non-aerospace industries; company willingness to invest technical and monetary resources in high-risk, distant-payoff ventures; acceptance by the financial community; development of markets for space products and services; and a great deal of advanced research to confirm that many theoretically attractive space projects are in fact economically viable. The next decade should provide a clearer view of whether these factors amount to real barriers or just low hurdles.

In the meantime, consensus of the most informed opinion leans toward the optimistic view. For example, The Center for Space Policy, a Cambridge, Massachusetts organization that specializes in evaluating space commercialization opportunities, predicts—by year 2000—annual revenues of $65 billion. And NASA Administrator James M. Beggs, the man best positioned to venture an opinion, sees cumulative revenues by 2000 in the hundreds of billions.

The following pages contain an illustrated summary of the status and outlook for space commercialization in five major areas of activity: space-based communications, remote sensing of Earth resources, ground launch vehicles, upper stages and space manufacturing.

SATELLITE COMMUNICATIONS

Demand for space-based communications relay has been increasing rapidly in recent years and will probably continue to do so despite some potential retardants. The first transatlantic fiber-optic cable is scheduled to go into operation about 1990; featuring very high transmission capacity and low cost, it poses a strong competitive challenge to satellite communications carriers. Crowding of the synchronous orbit where satcoms operate also threatens to limit availability of orbital positions.

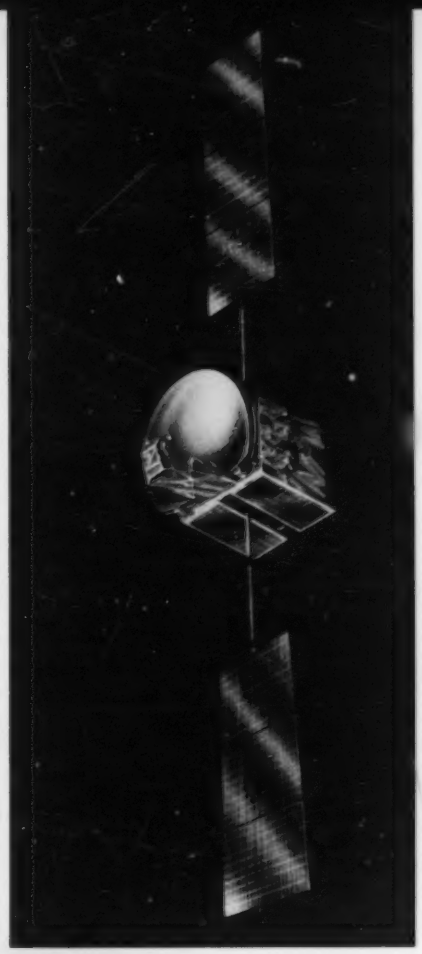
Communications carriers look to advancing technology to meet the latter difficulty. Government research agencies and satellite manufacturers are developing advanced technologies that will allow greater numbers of transponders per satellite, more effective employment of existing wavebands, and transmissions in a new band not yet in use—all combining to permit very large gains in individual satellite capacity.

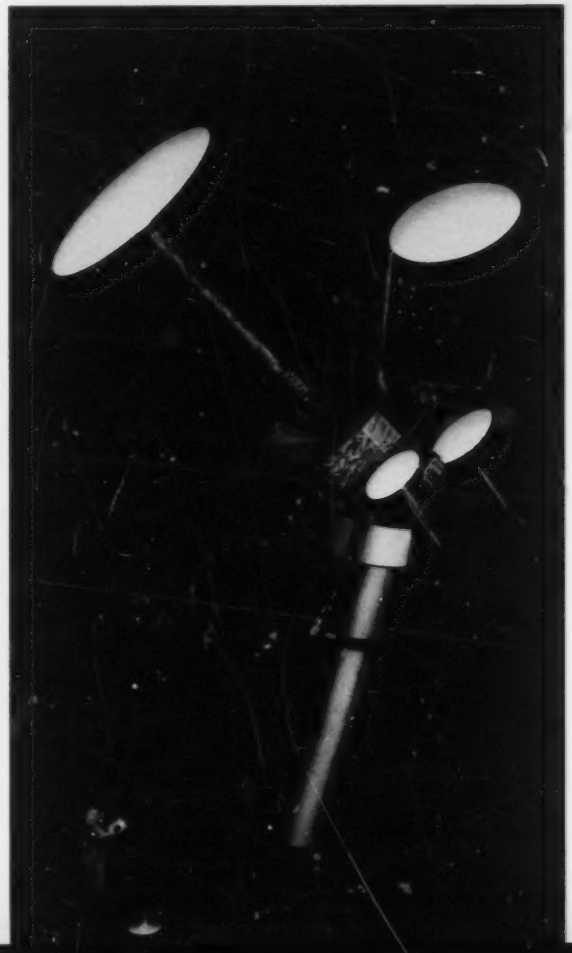
Such advances should also improve satellite operators' ability to compete with the upcoming cable system. Further, fiber optic cable transmissions will have their greatest competitive impact on international communications. There remain the large domestic and regional markets, particularly in the U.S. and Canada, continually expanding under the impetus of such new services as video teleconferencing, computer-to-computer linkages for business use, direct TV broadcast to home receivers and—the next step—mobile communications for truckers, railroads, fire, ambulance and rescue services, operators of small aircraft and private autos.

So, although cable competition may have a growth-limiting effect on the international segment of the space communications industry, the overall picture is bright. One study estimates that the number of transponders in orbit at the turn of the century will be up to five times the current figure. The Center for Space Policy sees, by the year 2000, space communications revenues of $15 billion annually, which would amount to a four-to-fivefold increase.

It seems likely that U.S. firms will capture the bulk of the revenues, because American companies have dominated both the satellite operating and satellite production segments of the industry. The U.S. Communications Satellite Corporation (Comsat) is the major entity in the 109-nation Intelsat consortium and Comsat subsidiaries are engaged in a variety of domestic and specialized services. Among other major operators are AT&T, ITT, IBM Corporation, GTE Corporation and Western Union, together with subsidiaries of Hughes Aircraft, RCA Corporation and Ford Aerospace, the Big Three of commerical satellite production. The Big Three have built all but a few of the more than 100 active commercial communications satellites in orbit.

But, since communications systems in Western Europe are operated by government postal-telephone-telegraph agencies (PTTs) committed to "buy national" policies, U.S. manufacturers are barred from the European market. A consortium of PTTs operates the European regional Eutelsast system; the satellites, developed under the aegis of the European Space Agency, are built by a British-led multinational group that includes French, German and Italian participation. Each of the latter nations is also building—or planning—a domestic satellite system to be built by its own industry. Japan has already launched a series of communications satellites and is developing a new, advanced-technology, high-capacity satellite. Canada is pushing a domestic mobile satellite communications system, which will become a North American system with U.S. participation. So there is—or will be—plenty of competition for U.S. manufacturers, but competitors will have a tough time overcoming the U.S. lead.





One of the most advanced communications satellites is Spacenet, built by RCA for GTE Spacenet Corporation; the first of three was launched last May.

This photo illustrates the dramatic increase in satellite size and capacity over two decades of satcom development: at bottom, Hughes Aircraft's 1965 Intelsat I, above it Hughes' new Intelsat VI targeted for 1986 launch.

EARTH REMOTE SENSING

Many familiar with the potential of space-based sensing of Earth's resources feel it has commercial possibilities of enormous order. The problem is that most of the world's business and government organizations that might use the technology to advantage are only vaguely or not at all aware of the potential.

Satellite remote sensing's broad utility stems from the fact that every Earth feature emits or reflects a different type of radiation, producing an identifying "signature" that can be detected by space-based sensors. Thus, satellite data can be computer-processed to differentiate among surface features and provide voluminous information that can be put to practical use in many ways; about 80 useful applications have been identified.

The U.S. Landsat system, the only one in operation, is providing data to many state and local governments, who use it in such applications as land use planning, tax assessment, parkland survey, pollution control and coastal zone management. It is also being used by business firms in oil exploration, mineral prospecting, mapping, agricultural crop forecasting and commercial forest management. A small industry has emerged, composed of companies providing ground-use equipment for processing remotely-sensed data and others that offer data processing and analysis services to users who do not care to invest in their own equipment.

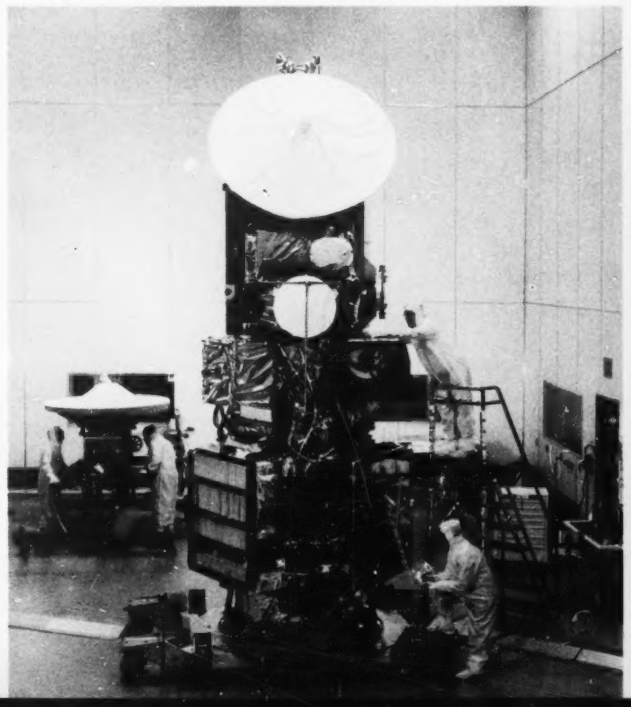
NASA developed and operated five Landsat satellites—built by General Electric's Space Systems Division—from 1972 until 1983, when the system was turned over to the National Oceanic and Atmospheric Administration of the Department of Commerce. With that experience and a solid user/supplier base, one might think that the U.S. has a very big lead in international competition. Such is not the case; in fact, it seems likely that the first truly commercial provision of remote sensing data—as opposed to the current government-provided service to commercial users—will be offered by a European group, the French-led SPOT Image Corporation. Other European and Japanese ventures are in development. In commercial remote sensing, foreign competitors see a good opportunity for leapfrogging the U.S. lead and they are going for it.

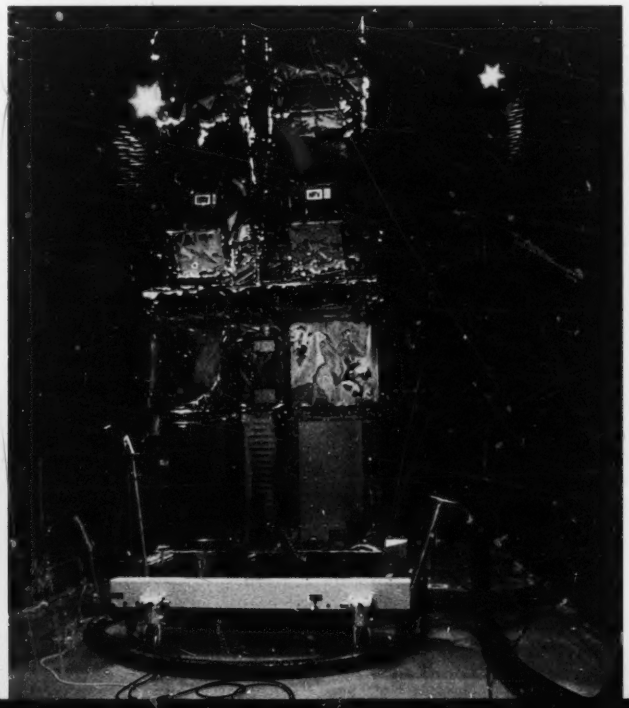
They got encouragement this year when U.S. plans to commercialize the Landsat system snagged. Congress authorized the Landsat transfer in July and subsequently, after evaluating several proposals, Commerce selected as the system operator Earth Observation Satellite Company (EOSAT), a joint venture of Hughes Aircraft Company and RCA Corporation. Under the agreement, the government was to provide $250 million, spread over several transitional years, for operation of the already-in-orbit Landsat 5 and for development and launch of a follow-on Landsat 6 in 1988. EOSAT was to build a ground station for processing and marketing Landsat imagery and eventually—after 1990—operate the system on its own and fund development of an advanced Landsat 7. But the Office of Management and Budget blocked the Administration's request for the transitional funding, so the U.S. commercialization program has stalled while the competition is moving rapidly.

SPOT Image is readying its first SPOT (Système Probatoire pour Observation de la Terre) satellite for launch next year and is conducting an aggressive marketing campaign. A second European group, the German-led SPARX project—which has American participation—has a competing system in advanced development. Japan has embarked on an ambitious program involving development of two separate types of land observation satellites for service beginning in 1986. Both Japan and the U.S. (NASA) are working on ocean-imaging satellites that could become commercial systems in the 1990s, expanding remote sensing activities to include valuable services to fishing and shipping industries and to government agencies concerned with such matters as coastal storm warning and maritime safety.

Commercial competition in remote sensing is expected to generate new techniques for improved data processing to make data more useful more rapidly, and to promote greater public awareness of the remote sensing potential. Successful efforts in those directions could mean end-of-the-century revenues on the order of $2 billion annually, according to an estimate by The Center for Space Policy.

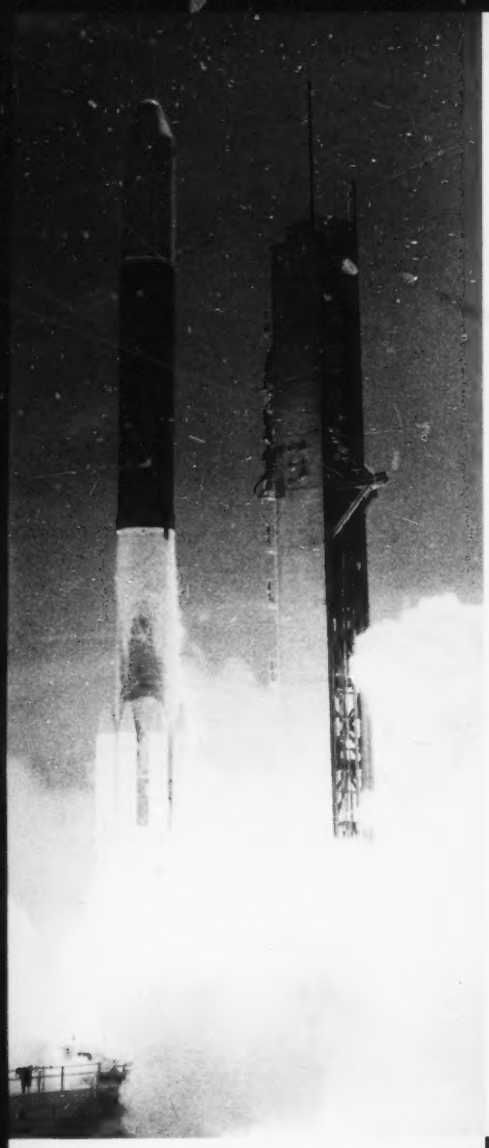
The leading contenders in remote sensing satellite competition: at left, the GE-built U.S. Landsat 5, launched in March 1984; at right, the European SPOT system, to be launched next year.



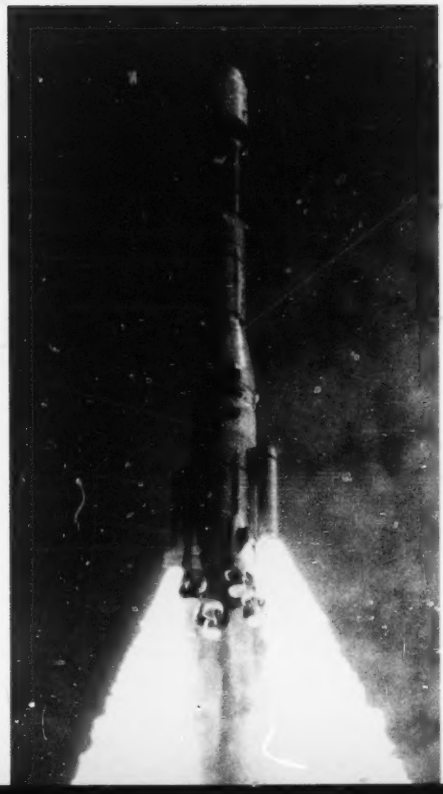


Courtesy CNES (France), SPOT Image Corporation

LAUNCH VEHICLES



Veteran of more than 170 launches, the McDonnell Douglas/NASA Delta is a prime contender for commercial operation.



Newest of the Ariane family—Ariane 3—entered commercial launch service in August.

For almost 20 years, the U.S. enjoyed a monopoly in providing launch services for commercial satellites. The monopoly ended last May when the European Space Agency's Ariane, after eight development flights, launched its first commercial payload under the aegis of Arianespace, the French-led commercial space transportation company. More recently, Arianespace introduced the more powerful Ariane 3, which delivered two communications satellites to orbit on an August launch.

Arianespace is proving to be a formidable competitor to the U.S. Space Shuttle. At last count, the company had firm orders for launching 26 satellites, a backlog worth some $875 million; it is developing a more advanced Ariane 4, intended for operational service in 1986, and France recently proposed to its ESA partners development—at a cost of more than $1 billion—of an Ariane 5 capable of delivering the heaviest payloads anticipated in the 1990s.

On the horizon is more foreign competition. Japan has in the works a medium-size H-1 vehicle, planned for service in 1988, and an advanced, heavy-lift H-2 booster designed to compete for international business in the 1990s.

In October, the Congress opened the door to a new phase of U.S. space commercialization by passing the Commercial Space Launch Act, designed to encourage growth of a U.S. launch industry. The law designates the Department of Transportation as the lead agency for approving private space launch operations with government-developed expendable launch vehicles (ELVs) now operated by NASA and the Air Force; it also authorizes DoT to license use of government launch facilities on a reimbursable basis and charges DoT with regulating launch safety.

Transpace Carriers Inc. is negotiating with NASA for commercial marketing and operation of the workhorse Delta vehicle, built by McDonnell Douglas Corporation. General Dynamics Corporation, prime contractor for the larger Atlas/Centaur, has submitted a proposal for commercial production and launch of that system. Another possibility for commercialization is the Martin Marietta-built Titan 34D, largest of the U.S. ELVs. And, before year-end, NASA is expected to solicit proposals for commercialization of the relatively small Scout ELV; several companies, including Scout builder LTV Aerospace, have expressed interest. In addition, NASA is weighing a proposal by Astrotech International under which the company would fund construction of a fifth Space Shuttle Orbiter for commercial operation.

NASA uses the term "privatization" to describe transfer of these launch vehicles to private builders/operators. The distinction between privatization and commercialization is that the former term applies to vehicles already developed to a high-degree of reliability under government funding; thus, privatization involves less risk to entrepreneurs and merits less government support than commercialization.

There are, however, launch vehicle projects that were designed from the beginning as commercial ventures. One is the Conestoga booster for small payloads, designed by Space Services, Inc. of America; the company successfully launched a prototype Conestoga 1 in 1982 and is developing a family of more advanced versions. Another company—Starstruck, Inc., currently undergoing reorganization—launched its Dolphin sounding rocket in August; the Dolphin is the first step in a plan to develop an orbital launch vehicle designed for the communications satellite market. Other U.S. firms have announced plans for launch vehicle developments but have not reached hardware status.

The outlook for U.S. commercial ELV operation is difficult to assess, since operators must compete with both Ariane and the Shuttle. The Center for Space Policy estimates annual revenues by year 2000 of $1 billion—for all commercial boosters.

UPPER STAGES

An upper stage, also known as a transfer orbit system or a payload assist module, is a secondary booster employed to propel satellites to high altitude orbit or deep space trajectory. The Space Shuttle Orbiter, for example, operates by design at altitudes below 700 miles, so Orbiter payloads destined for geosynchronous orbit (22,300 miles) are deposited in low Earth orbit affixed to an upper stage propulsion/guidance system that propels the satellite to its requisite high altitude position. Upper stages are similarly employed with expendable launch vehicles (ELVs).

The first commercial upper stage was the PAM (Payload Assist Module) developed by McDonnell Douglas Corporation with company funding. PAM was initially developed in two versions, one for use with the McDonnell Douglas/NASA Delta ELV and another for Shuttle launch. Powered by Morton Thiokol solid rocket motors, the two types of PAMs have successfully launched 20 satellites, their record marred only by failures on a February 1984 Shuttle flight when two satellites were sent into wrong orbits.

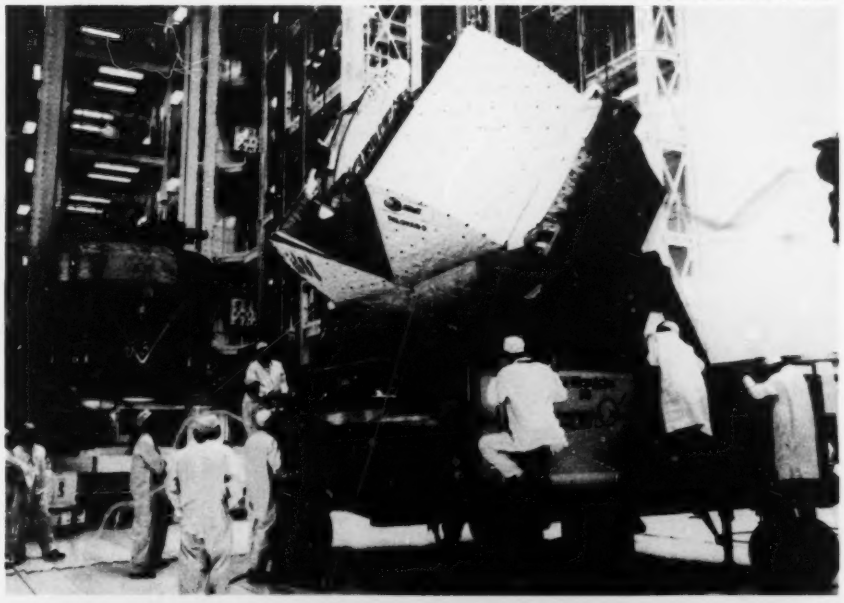
McDonnell Douglas is developing two larger versions for delivering larger satellites: a PAM-DII for Shuttle use and a PAM-A for use with Atlas; both will be ready for service next year. In cooperation with Astrotech International McDonnell Douglas is also developing an upper stage based on the second stage of teh Delta vehicle.

NASA and the Air Force are also using the Boeing-built Inertial Upper Stage for heavier payloads and are developing advanced versions of the General Dynamics Centaur for even larger payloads. Neither has commercial assignments because their heavy-boost capabilities are not needed for current generation commercial satellites, but both have commercialization potential for the future, when satellites get bigger.

Several companies are planning or considering development of upper stages but only one other has moved as far as hardware status: Orbital Sciences Corporation (OSC). Formed in 1982, OSC is a financing/marketing firm which has raised some $95 million for initial funding of four Shuttle-use systems. They include the medium-capacity Transfer Orbit Stage (TOS); a shortened version for smaller payloads, the TOS-S; an Apogee and Maneuvering Stage (AMS); and the TOS/AMS, a two-stage system for boosting large payloads. For development and construction of these systems, OSC has teamed with several space-experienced aerospace companies: Martin Marietta Denver Aerospace, prime contractor; United Technologies' Chemical Systems Division, TOS solid rockets; Aerojet Technical Systems Company, AMS liquid rockets; Honeywell Inc., avionics; and Lockheed Missiles & Space Company, stage separation.

In development by each of the Big Three communications satellite manufacturers—Hughes Aircraft, RCA Corporation, Ford Aerospace—is the integral upper stage, a self-contained boost system that would obviate the need for a separate upper stage in launching some types of satellites. This technology clouds the market potential of the McDonnell Douglas and OSC systems, but both companies express optimism. McDonnell Douglas sees 75 firm or potential missions for its PAMs over the next seven years. OSC's market assessment projects a total demand for 250 to 300 launches through 1995.

Its clamsheli doors encasing a Telstar satellite, a McDonnell Douglas PAM upper stage is unloaded at Kennedy Space Center preparatory to installation in the Space Shuttle Orbiter.



A new entry in the commercial upper stage competition is Orbital Sciences Corporation's two-stage TOS/AMS. The TOS (Transfer Orbit Stage) is the lower unit; the AMS (Apogee and Maneuvering Stage), shown mated to a satellite, delivers the final kick into orbit.

SPACE MANUFACTURING

The first commercial products made in space will go on the market soon. They are latex "microspheres", about one billion of them, of perfect spherical uniformity and all exactly the same size—one hundred thousandth of an inch in diameter. They are used by research and industrial laboratories for instrument calibration and other applications in the field of medicine, oil, chemicals, glass and metallurgy. Such spheres fill a long-standing need because they cannot be produced on Earth in the sizes laboratories want, due to the effects of gravity. NASA made the spheres on five Shuttle flights and turned them over to the National Bureau of Standards for certification,packaging and sale.

Microsphere production is not the most dramatic example of the space manufacturing potential, but NASA undertook the project to demonstrate the utility of space materials processing and encourage broader interest in this technology, which allows production of a great range of items not producible on Earth because of the adverse effects of gravity and air.

The most notable effort thus far is the Electrophoresis Operations in Space (EOS) program conducted by McDonnell Douglas Corporation and its EOS partner Johnson & Johnson. The EOS project is aimed at separating biological materials—cells, enzymes hormones and other proteins—in sufficient quantities and purities to enable production of pharmaceuticals for more effective treatment of many diseases. In Shuttleborne tests, the EOS system demonstrated its ability to produce more than 700 times the material that could be extracted from similar Earth processing, with a fourfold increase in purity. McDonnell Douglas and Johnson & Johnson hope to make their first pharmaceutical product available for public use within this decade.

In addition to pharmaceuticals, there are a great many other possibilities, for example, silicon crystals with enormously improved electrical properties, offering great advances in electronics; extremely pure glass for such applications as lasers or optics; and vastly superior metallic alloys for a multitude of uses.

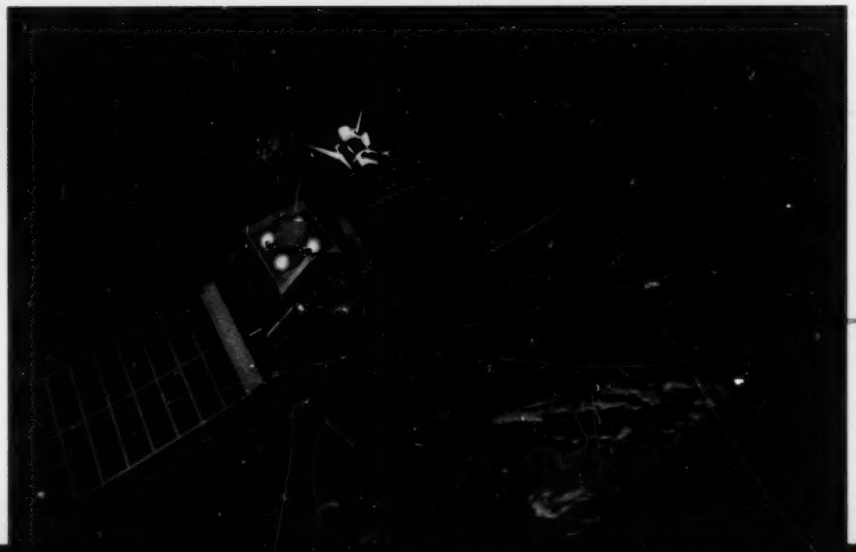
Major manufacturers are gradually becoming more aware of the space manufacturing potential. Many, including such big names as Alcoa, General Motors, Union Carbide and Westinghouse—are conducting studies and ground experiments with an eye toward actual space research. About a score of companies have already signed or are negotiating agreements with NASA for orbital research. For example, 3M Corporation, already engaged in space experimentation, is negotiating a product development program involving as many as 72 Shuttle flights over the next 10 years. The farm equipment firm Deere & Company is also involved in space research, but with a different perspective: Deere has no plans to manufacture products in space, but wants to study iron processing under weightless conditions with the aim of developing new Earth processing techniques for improving the strength and quality of cast irons.

A number of companies are pursuing another line of commercial opportunity: producing furnaces and other processing equipment for sale to researchers. One company—Bali Aerospace—is developing a complete Shuttle-based materials processing plant. Fairchild Industries, in cooperation with NASA, is developing a free-flying platform to support a Shuttle-tended orbital factory; called Leasecraft, it is targeted for flight in 1988.

Studies indicate that there are some 500 materials that could be advantageously processed in space. How many of them will result in viable commercial products remains to be seen; similarly, there is question as to how many industrial firms will commit to large-scale research outlays toward products of uncertain marketability. But the ranks of space-interested companies are already swelling under the impetus of the McDonnell Douglas/NASA pioneering efforts. The prospective availability of a space station with permanent research/manufacturing facilities should spur greater interest. McDonnell Douglas forecasts sales of $1 billion a year, by the mid-1990s, for its initial drug product—and the company hopes to be processing as many as 10 new pharmaceuticals by the end of the century. The Center for Space Policy sees annual revenues—by year 2000—of more than $40 billion in pharmaceuticals ($27 billion), space-processed glass ($11.5 billion) and semiconductors ($3.1 billion).

McDonnell Douglas engineer Charles D. Walker, who became the first commercial astronaut last August, is shown calibrating the EOS materials processing system carried on the mid-deck of the Shuttle Orbiter.

Fairchild Industries' Leasecraft, planned for first flight in 1988, is a Shuttle-retrievable orbital platform designed to support space manufacturing operations.



PRODUCTIVITY IS US

By MALCOLM T. STAMPER
President, The Boeing Company

Malcolm T. Stamper joined The Boeing Company in 1962 after 14 years with General Motors. Initially he directed the company's aerospace electronic operations; later he served as general manager of the Turbine Division, general manager of the Boeing 747 Division, general manager of the Commercial Airplane Group, and corporate senior vice president-operations. In September 1972 he was elected president of The Boeing Company and a member of the board of directors. He also serves on the boards of the Smithsonian Associates, The Nordstrom Company, The Travelers Insurance Companies and Chrysler Corporation. This article is excerpted from his speech at the NASA Symposium on Productivity in Washington, D.C.

We're talking productivity in the aerospace industry. Not as exciting, perhaps, as touching off the first moon rocket, but it's vital if we're to homestead the space frontier. The aerospace industry is also the sturdy foundation for our Triad national defense strategy—our submarines, B-52s, and Minuteman missiles. In these, as in all our military products, we have a very low tolerance for failure. We in aerospace have our own "triad strategy"—performance, reliability, superiority. Coming in second in a bi-polar world clearly isn't useful. Being Number One is not a goal—it's an imperative.

Pride in American aerospace runs deep. We employ 1,200,000 people and jobs are on the rise. We have 100,000 scientists and engineers doing research and development, nearly 20 percent of the national total. Sales last year exceeded $75 billion—2.3 percent of the Gross National Product. Our industry's backlog is $120 billion. And at a time when our nation's trade deficit is at an all-time high, we can be proud that our industry is part of the cure, not the cause. We contributed a *positive* $12.6 billion to America's balance of trade last year. As an industry, we paid $1.7 billion in federal, state, and local taxes last year, contributed millions to the communities where we work and invested $5.5 billion in new plants and equipment.

Our industry is part of the reason why American business productivity continues to grow at a healthy rate—4.7 percent in the second quarter of this year, the eighth quarter in a row and the longest string of productivity increases in a decade.

Our track record is good. We have the right stuff. We have the ingredients not ony for improving but sustaining high productivity. America is rich in the assets that count: a free society, immense natural resources, industrial maturity, a proven reputation for innovation, unexcelled technical competence, and confidence, born of experience, that the sky is no limit to progress.

So in America we have the resources, we have the leadership and we have the people—especially the people—capable of creativity, high productivity and uncompromising quality. Quality and productivity go hand in hand—the more we improve quality, the lower our costs are going to be.

We are all responsible for making the product better, improving productivity and working "smarter". And instead of executives looking to Washington and labor looking to the board rooms and the public looking to their elected officials, the truth is that when it comes to improving productivity, we should all look to ourselves first.

As Ruben Mettler of TRW said recently: "In the arena of global competition, the battle is no longer just between industry and industry, or company and company, each seeking a comparative advantage largely on its own. Being competitive today is a matter of what society does: it is government, managers, employees, unions, educational institutions, consumers and taxpayers—all together, all part of the action." Let's take a look at the initiatives to improve productivity that each of us can take—government, management, employees, newspersons and the public.

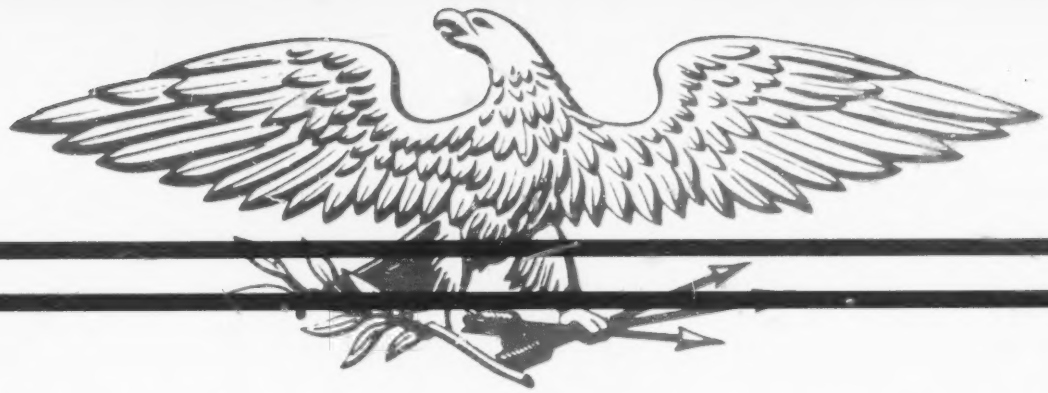
Government Initiatives

First, government itself has responsibilities to enhance productivity. It needs to sponsor research and development, enact effective tax legislation, promote export incentives and develop progressive international trade policies, stimulate competition and keep a tight rein on regulation, carry out a balanced monetary policy and reward investment. Government does not owe American industry a living, but it is charged with the responsibility of developing an environment where business can compete fairly, operate efficiently, and invest with confidence for the future. Government needs to encourage statesmen who are sensitive about the power they've been given over the institutions of our society and who don't easily tear them down on flimsy evidence and incomplete facts—sacrificing honest effort for political expediency.

Management Initiatives

Second, management's role in improving productivity is critical. Management functions at the front lines of risk, product development, research and development, market growth, and employee motivation in an environment of ever-changing ground rules. It must provide the facilities and tools that speak to productivity—and be ceaseless in its search for better ways to make things. It must set an example by practicing fairness and proper constraint in executive compensation. Management must be willing to take the "Big Risk".

The ground rules in business, as we know, change. Virtually a company's sole report card not too many years ago was the "bottom line"—dollars and cents, profit or loss. That attitude doesn't go very far today. Not that profit isn't important; we have the stockholders' word on that. But the bottom line for world class companies today is more complicated. It's now a composite—in part financial, of course, but also required to take into account environmental, social, and human values as well.



Employee Initiatives

Thirdly, for all that government and management do, our employees remain the key in our quest for new pinnacles of productivity. The $3,514,900 in suggestion awards that our Boeing employees earned last year on 16,547 suggestions speak to that. Yet interestingly, we still fall short of the average Japanese industrial worker who turns in 25 suggestions per year. Our employees will take an increasing personal interest in the welfare of our companies when we give them the opportunity, encouragement, and reason to do so. They'll produce when motivated!

Newsmaking Initiatives

And fourthly, there is yet another element to the productivity equation—one we might not usually consider. I refer to those who report the news, the watchdogs of our society.

All of us who have felt the sting of an incomplete story sense the frustration of trying to achieve the balance we feel is due. Yet, as companies receiving public dollars, we know we operate in a "fishbowl" environment, and that we need to be accountable not only to our stockholders but to the American people. We must not only be upright and productive, we must be *perceived* in that light.

"The public is not 'they.' The public is 'us.' We all have a vested interest in making America work better and smarter. We will be successful when we are bound together in mutual trust."

we take in our performance, the confidence we have in ourselves and in the morality of our motivations. America has always been a productive society. We've led the world in this area since the beginning of the industrial revolution and have known we were good—everybody sensed it. But has doubt crept in? Have the people who report the news, who are just as competitive as every other industry, and seek the "big story," have they relentlessly exposed every infraction, every failure, every weakness, till perhaps we are no longer sure of ourselves or the purity of our motives? The need for free speech and open forums is sacred to our free society and not negotiable, but opinion versus fact—and balance of story—perhaps are.

What I'm suggesting is an initiative by the newspersons to look beyond the headline, to see every story in perspective. Not to *fail* to report to the American people, but to report the positive along with the negative, so that the end result thereby, demanded by the public, is not more costly to our taxpayers or our security—that the cure isn't worse than the disease. Perhaps, then, the concept of a "balanced story" must reach out further, take in more ground, require more work and thereby be more useful to society and help render us more productive.

Public Initiatives

Lastly, the public also has a part to play in making our society more productive. The people, in the final analysis, determine where taxes are spent, what problems they want fixed, what course our laws take, and what programs merit federal support because they choose who's to govern us. But in saying this, let's remember who the public is. They are management, newspersons, employees; the people we buy from and sell to; passengers on our planes; and citizens of our communities. A cross-section of America, subject to the same interests, concerns, and ambitions we all share. The public is not "they." The public is

My concern is this: that in their zeal, those who report the news may in fact be inadvertently endangering the pride "us." We all have a vested interest in making America work better and smarter. We will be successful when we are bound together in mutual trust, when we realize that the people who are both making and using the systems to defend us, are American citizens too—that the 1,200,000 aerospace workers in America are on our side and we should not be so ready to write them off because of a glib story or two about a hammer, a stool cap or a coffeemaker. Instead, we're going to also look at what they have done right and not just what they haven't done right. Their performance can stand the test.

Less than a century ago one of America's premier inventive geniuses—Thomas Edison—dismissed aviation as impractical. "It is apparent to me," he said, "that the possibilities of the aeroplane have been exhausted and we must turn our attentions elsewhere."

Eighty years ago Octave Chanute, one of our first aviators, said: "Airplanes will be used in sport, but they are not to be thought of as commercial carriers."

Along with a host of other detractors, aviation pessimists down through the years have been proven wrong. Today is no different. There are those quick to count the reasons why we can no longer fly faster, higher or farther. Whatever the reasons—costs, safety or technology—their arguments defy the American tradition. As President Reagan said a few weeks ago: "There is nothing the United States of America cannot accomplish if the doubting Thomases would just stand aside."

As individuals, or as a civilization, we only go around once. Our goal should be building, not belittling. We can pull together or polarize our society—spark a renaissance or sink in despair. The profit from productivity is measured not in balance sheets alone, but in the quality and security of life in our country and on this Earth now and tomorrow.

Probing Flight Frontiers at

ARNOLD ENGINEERING

Latest addition to Arnold Engineering Development Center is the 57-acre Aeropropulsion Systems Test Facility where – beginning next September – air-breathing engines of 75-100,000 pounds thrust will be tested.

The complex of ground test facilities operated by the Department of Defense, NASA and industry companies is a vital part of the U.S. aerospace research and development capability. Simulation in ground facilities does not eliminate the need for flight testing, but it sharply reduces the flight test time required and compresses total development time for a new system; most importantly, it affords significant savings in the cost of readying a system for operational service.

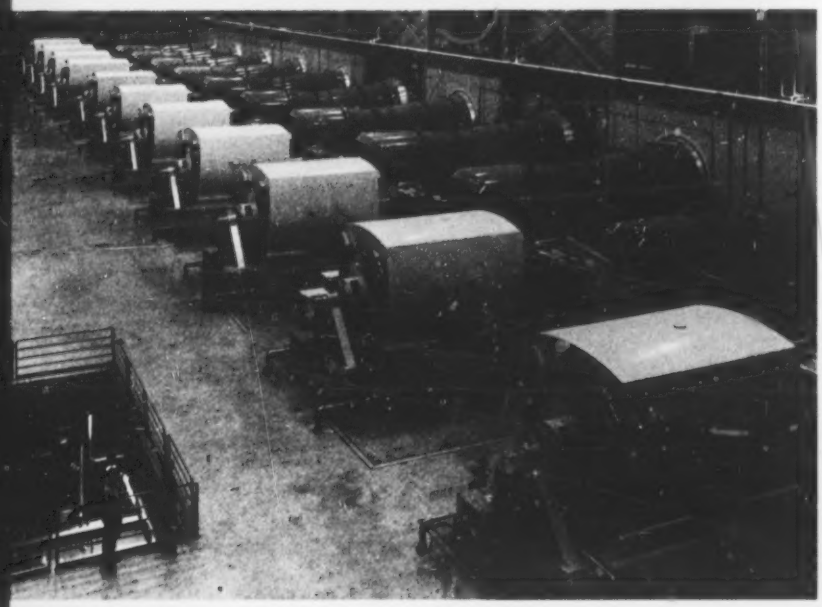
Ground simulation's big advantage is that the many variables of the flight "envelope" can be precisely controlled and test results fully documented by sophisticated instrumentation. Using less expensive models rather than flight hardware, researchers can expose a test vehicle to best, normal and worst conditions, test it over long durations and run it through repetitive cycles. After these preliminaries, flight tests can be conducted with far greater safety and confidence in the system's reliability.

An important addition to the U.S. ground simulation complex is the Air Force's Aeropropulsion Systems Test Facility (ASTF), dedicated in October after seven years in construction. Scheduled to begin operation next year, ASTF will enable gound test of air-breathing engines—military and civilian—two to three times the size of any currently in use. It will more than double the nation's engine test capability, providing an environment that will simulate all conditions of flight—takeoff, climb, multi-speed maneuvers, descent and landing.

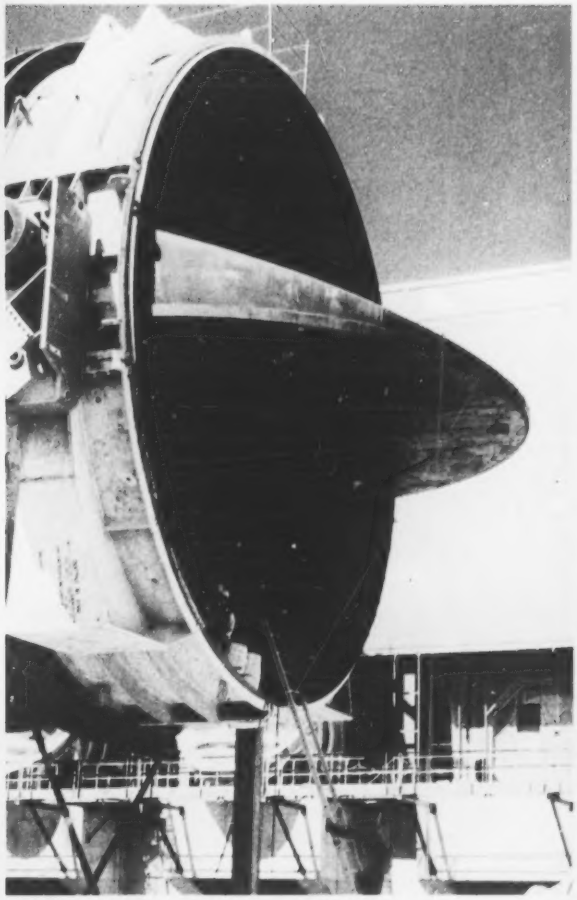
ASTF is part of the USAF's Arnold Engineering Development Center (AEDC), named for General H. H. "Hap" Arnold, who was the driving force behind the center's creation. Built in 1950-53 and frequently updated by additions and modifications, AEDC sprawls over more than 40,000 acres of middle Tennessee. It is the largest and most advanced flight simulation complex in the free world, containing 40 major facilities, 27 of them with capabilities unmatched elsewhere. These facilities, which use some 325 million kilowatt hours of electricity a year, simulate flight conditions from sea level to 1,000 miles altitude, velocities, from subsonic to more than 20 times the speed of sound. AEDC's major components are:

- The Engine Test Facility, which has 11 cells for testing propulsion systems of aircraft, missiles, spacecraft and space launch vehicles. It includes the world's two largest high-altitude simulation cells, one for testing solid propellant rockets with thrust up to 125,000 pounds, the other for liquid and solid rockets up to 500,000 pounds thrust.
- The Propulsion Wind Tunnel Facility, which has two 16-foot tunnels—one transonic and one supersonic—for testing full-scale engines, large aircraft and missile models, and some full-scale missiles; a four-foot transonic tunnel for certifying that an aircraft can safely carry or release external "stores" —bombs, missiles or fuel tanks—at critical flight conditions; and a one-foot transonic tunnel used to evaluate proposed improvements to the larger tunnels.
- The Von Karman Gas Dynamics Facility, which has four high-speed wind tunnels for testing relatively large-scale aircraft/missile models at flight conditions ranging from Mach 1.5 to Mach 10; four ballistic ranges, in which models travel in free flight at velocities up to 30,000 feet per second; and four high-vacuum space chambers for testing full-scale spacecraft and subsystems.
- The Aeropropulsion Systems Test Facility, which has two large cells for subsonic and supersonic testing of the more powerful jet engines of the future—engines with thrust rating of 75-100,000 pounds—at speeds up to Mach 3.8, with airflow cooled or heated to simulate specific flight environments.

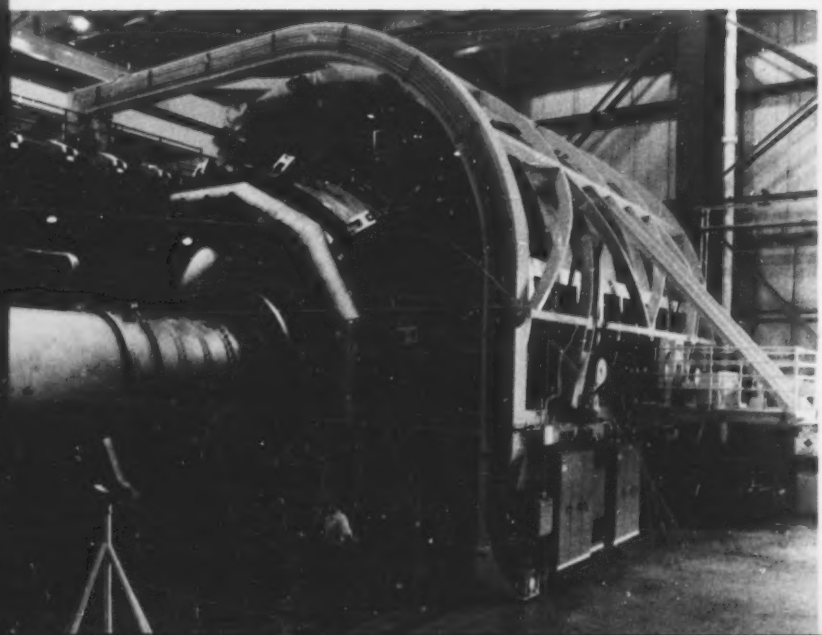
DEVELOPMENT CENTER



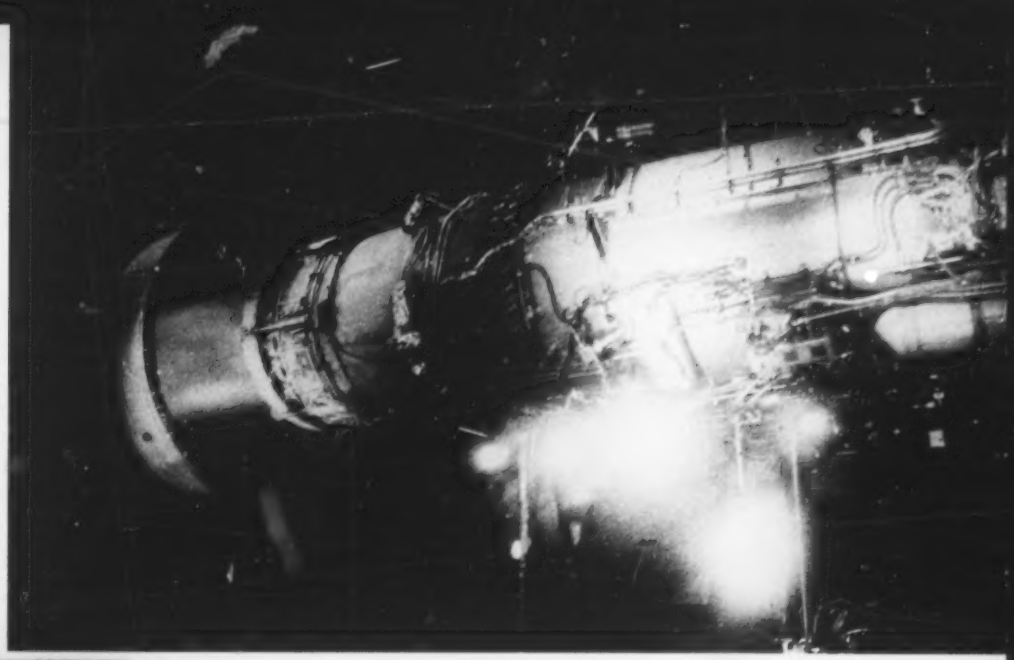
In the Aeropropulsion Systems Test Facility (ASTF), test airflow is drawn from the atmosphere, compressed and fed to the two largest air-breathing engine test cells in the world. The exhausters pictured, driven by 12 motors with a combined 396,000 horsepower, create low pressures within the test cells to simulate high-altitude flight; they also capture and treat exhaust gases before venting them into the atmosphere.



This 170-ton butterfly valve, the world's largest, isolates one bank of exhausters from another while controlling the pressure and volume through ASTF's test cells.



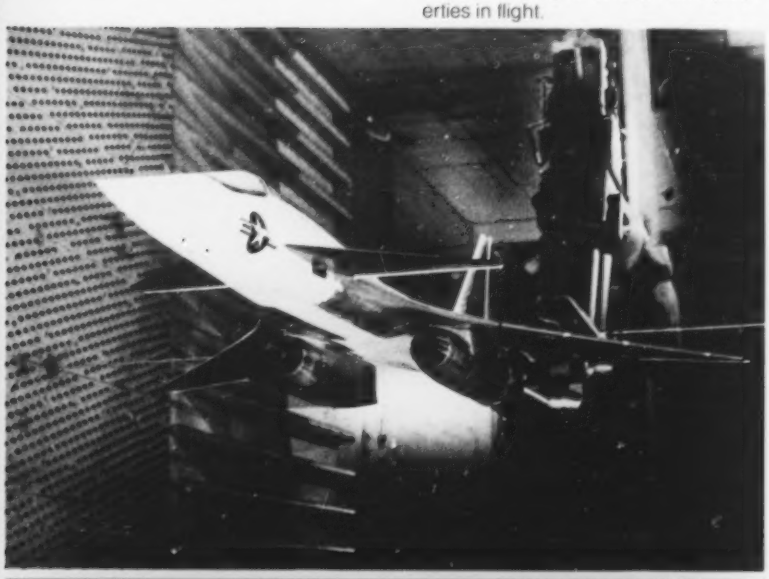
One of ASTF's two test cells, shown open; during a test, a 52-ton hatch covers the airflow ducting. Eighty-five feet long and 28 feet in diameter, the cell accommodates full-scale engines mounted in portions of the airframe that would affect airflow during flight.



In an altitude test cell of the Engine Test Facility, a General Electric F101 engine undergoes evaluation. To simulate high altitude conditions, the airflow entering the engine's inlet was chilled to minus 65 degrees Fahrenheit. For this test, engineers simulated an altitude of 64,000 feet and aircraft speeds ranging from subsonic to more than twice the speed of sound.

Among the 11 cells of the Engine Test Facility is the J-4 vertical test cell, which can simulate high altitude operation of rocket engines with thrusts up to 500,000 pounds. The exhaust gases come down through the large duct pictured, then are directed through a maze of cooling water spray pipes before being pumped out to the atmosphere.

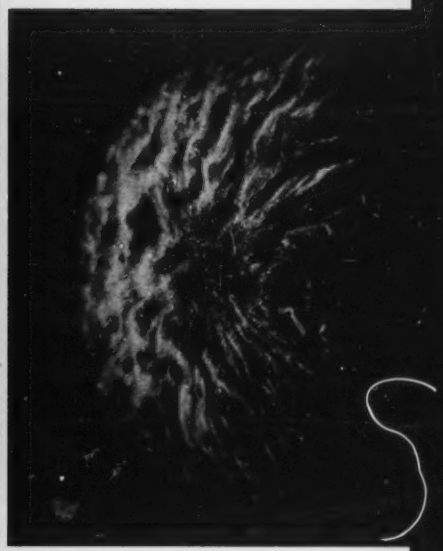
Ready for test in the PWT's 16-foot transonic tunnel is a one-eighth scale model of an advanced fighter concept. This design features forward canards instead of a horizontal tail and a main wing capable of changing its aerodynamic properties in flight.



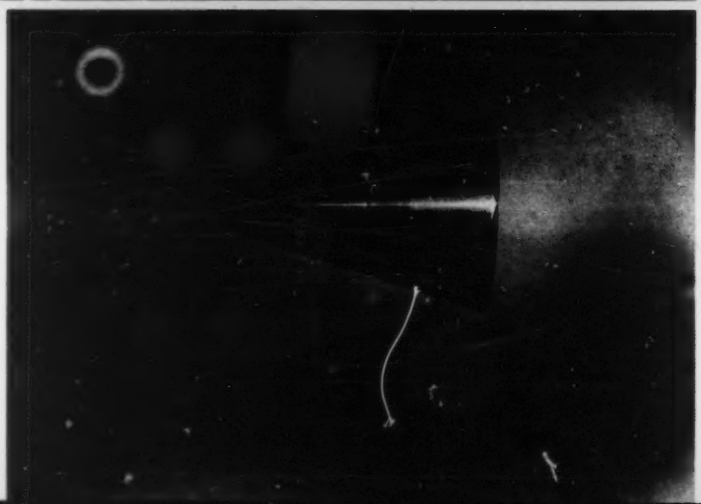
The Propulsion Wind Tunnel Facility (PWT) includes one supersonic and three transonic tunnels. In the photo is the main compressor of the 16-foot supersonic tunnel.

Part of the Von Karman Gas Dynamics Facility (VKF), this is one of four high vacuum space chambers in which full-scale spacecraft can be subjected to launch pressures, vibration, space vacuum, radiation and altitude conditions up to 1,000 miles.

The VKF's 40-inch variable density supersonic tunnel can simulate speeds from Mach 1.5 to Mach 6; airflow velocity is controlled by use of 80 electrically-driven jacks to vary the contour of the two flexible steel plates pictured.



This color-enhanced laser photograph pictures an in-flight evaluation of a transpiration-cooled nosetip technique, in which thermal protection of a missile nosetip is provided by a cooling layer of water. Purpose of this test, conducted in the VKF's hyperballistic range, was to determine how much coolant is needed to keep the nosetip from melting. The nosetip was flying at 16,000 feet per second when the photo was taken.



Ultra-high-speed cameras spaced along the VKF's 1,000-foot ballistic range provide stop-action photography while a model is traveling at speeds up to 20,000 miles per hour. In this view, a missile nose cone model flying at 12,300 miles per hour is "frozen," enabling observation of surface details and shock waves.

CAREERS IN AEROSPACE:
A BROAD HORIZON

In response to requests from the aerospace educational community, Aerospace magazine presents this summary of career opportunities in the aerospace industry.

Aerospace is the huge aircraft that can whisk 300 passengers across the United States in a few hours. It is launch vehicles and spacecraft that can put men and women into space and bring them back. It is satellites that study Earth's resources and weather, and bring distant events into your living room as they are happening. It is superior missiles, bombers, and fighter aircraft, and other weapon systems that the nation needs for its defense. It is business and personal aircraft that provide pleasure or quick, convenient travel for busy people. It is helicopters that can do anything from rescuing accident victims to serving offshore oil rigs.

And aerospace is much more. Technological advances in space have found everyday use in fields as diverse as medicine, agriculture, communications, meteorology, energy, building design and manufacturing. Aerospace has affected the development of products as ordinary as coke bottles, as invaluable as heart pacemakers and as critical as devices for early detection of radioactive leakage.

While aerospace literally took off from incredible advances in the science of aerodynamics, it has developed solid production roots in a manufacturing industry that provides jobs for well over a million Americans in research, development and production of aircraft, missiles, spacecraft and associated equipment. Thousands of workers in other industries produce parts, machinery and equipment used in aerospace and thousands of federal employees work in aerospace-related jobs because of the government's role as a prime purchaser of industry products.

Industry sales are at near-record levels and a booming future is predicted as defense expenditures continue to rise and airlines modernize their fleets. Because of the U.S. aerospace industry's technology lead and quality products and services, foreign sales remain a major pillar of the industry; a high percentage of aerospace workers owe their jobs to sales abroad.

THE INDUSTRY'S PRODUCTS

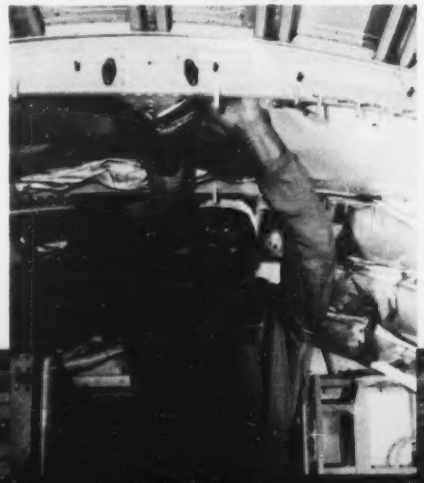
Aerospace firms produce primarily aircraft, missiles, spacecraft and space launch vehicles, all of which have the same basic components: an airframe, an engine—either piston, jet or rocket powered— and a guidance and control system.

Industry customers include the U.S. government, foreign governments, commercial airlines, and private firms and individuals. In the U.S., aerospace product and service sales to the government generally exceed non-government or commercial sales.

Aircraft—including transports, bombers and fighters for military use, and aircraft for commercial passengers, freight airlines and private use—represent the largest component of industry sales. Missiles are purchased by the government for military use. Spacecraft are used by the National Aeronautics and Space Administration (NASA) and the Department of Defense to explore space, to examine the Earth's surface and atmosphere, and for practical applications, such as communications. Sometimes NASA places communications, navigational or research satellites into orbit for private companies or for other countries.

When a major aerospace firm contracts with government or private business to produce an aerospace vehicle, the firm

Assembly and installation workers include final assemblers of aircraft, missiles or rockets, and assemblers specializing in other systems such as power plants, electrical wiring, heating, ventilation and plumbing. Here a worker applies wire-protecting insulation to the interior of a commercial jet liner.



Technicians work to apply final touches to the Shuttle Orbiter *Atlantis*, to be launched by NASA in 1985.

Engineers confer on plans for developing an aircraft-related system.

is responsible for managing and coordinating the entire project, including design and manufacture. Although the prime aerospace manufacturers make many components of a vehicle and do final assembly themselves, thousands of subcontractor firms provide parts and supplies—from bearings, fasteners and nuts and bolts to specialized metal parts and seats—and other equipment required for the "fitting out" of aircraft. Subcontractors also produce the propulsion systems, landing gear, electronics and hydraulic equipment—sometimes entire subassemblies of an aerospace vehicle. Still other firms may supply parts of subassemblies. It is an interrelated process, involving thousands of U.S. companies and extensive resources.

OCCUPATIONS IN AEROSPACE

Aerospace involves extremely complex technology, so firms in the industry need workers with many different types of skills. Most jobs in aerospace manufacturing are either professional and technical occupations, management and administrative occupations, or plant occupations.

Professional and Technical Occupations

Many types of engineers, scientists and technicians work together developing designs for aircraft, missiles and spacecraft. Aerospace, chemical, electrical, electronics, industrial and mechanical engineers are among the larger groups of engineering specialists. Aerospace engineers work mainly in the aircraft and parts industry, often specializing in such areas as structural design, engines, navigational guidance and control, instrumentation and communication, or production methods. Scientists include physicists, mathematicians, chemists, metallurgists and astronomers, among others. Both engineers and scientists work in a wide range of applied fields such as materials and structures, energy and power systems, and space sciences.

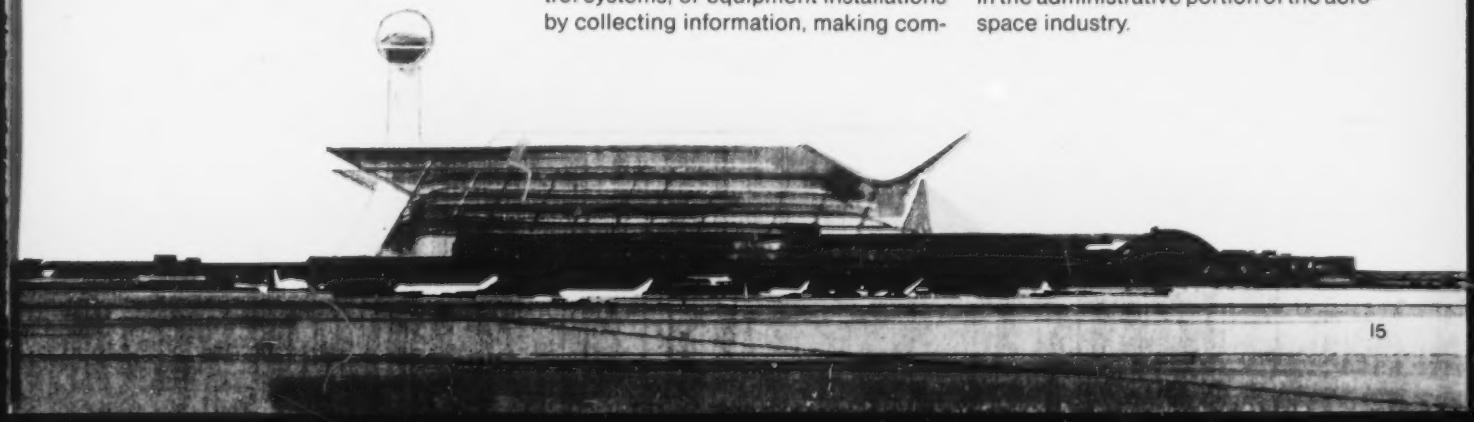
Drafters assist engineers and scientists. They prepare detailed drawings based on rough sketches, specifications and calculations made by engineers and scientists. Final drawings include a detailed view of the vehicle from all sides, specifications for materials, and other necessary information.

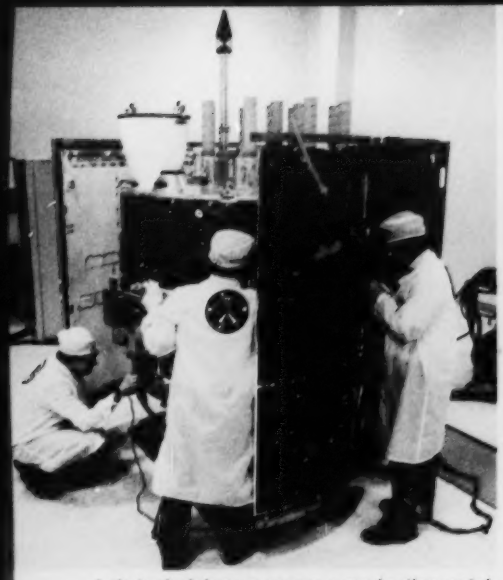
Technicians aid in preparing designs, layouts and models of structures, control systems, or equipment installations by collecting information, making computations, and performing laboratory tests. They may prepare specifications for materials or supervise production workers to be sure plans are followed. Some technicians serve as manufacturers' field service representatives—the link between the company and its customers.

Also assisting scientists and engineers are production planners who develop layout of machinery, movement of materials and the sequence of operation for manufacturing processes, and technical illustrators who help prepare manuals and technical literature describing operation and maintenance of products.

Management and Related Occupations

Managerial and administrative jobs in aerospace are comparable to similar jobs in other industries except these positions in aerospace are often filled by people with backgrounds in engineering or science. Such positions include executives responsible for direction and supervision of research, development and production and officials in sales, purchasing, accounting, industrial relations, and public relations. Many thousands of clerks, secretaries, computer personnel and other office workers are employed in the administrative portion of the aerospace industry.





Lab technicians prepare a navigation satellite for launch into space.

Overview of a plant where assembly of aircraft, missiles and rockets takes place.

Plant Occupations

About half of all workers in aerospace have plant or production-related jobs. Plant occupations include: sheet-metal work; machining; tool fabrication; other metal processing; assembly and installation; inspecting and testing; flight checkout; and materials handling, maintenance and custodial.

TRAINING AND QUALIFICATIONS

A college degree in engineering or one of the sciences is usually the minimum requirement for an entry position in aerospace as an engineer or scientist. Technicians sometimes can achieve these positions without a degree, but only after years of experience and some formal training. An undergraduate preparing for a career as an aerospace engineer or scientist should get a solid background in mathematics and physics. More specialized fields of the industry require graduate school education or on-the-job training.

Technicians generally attend a technical institute or junior college or receive training in the armed forces. Highly skilled plant workers may advance to technician levels by taking courses in areas such as metallurgy, electronics or drafting.

Entry-level plant occupations generally do not require a degree, although a high school diploma and vocational courses in electronics or mechanics are preferred—especially for more skilled, higher paying jobs. Inexperienced workers generally start in semiskilled positions and learn on the job or in courses provided by employers. With experience, they can move into more highly skilled positions.

Apprenticeship programs, lasting about four years, are available for craft occupations such as machinists, tool-and-die makers, sheet-metal workers, aircraft mechanics and electricians. The programs vary from three to five years in length, during which the apprentice handles work of progressively increasing difficulty. Because of rapid changes in technology, firms also supplement day-to-day experience through short-term training programs.

EMPLOYMENT

The aerospace industry employs about 1,200,000 workers. About half of those work in production, while nearly one-fourth find employment as scientists, engineers and technicians. Aircraft manufacture generally accounts for more than 50 percent of industry employment and missiles and spacecraft manufacture for more than 20 percent. Another 25 percent of workers are involved in manufacture of other products such as avionics. Production workers are the largest group of employees in every segment of the industry.

Aerospace jobs exist in almost every state, but the highest concentration of employees is in the Pacific states, especially California and Washington. The New England region ranks second. New York, Texas, Missouri and Kansas all have large numbers of aerospace jobs.

OUTLOOK

Total aerospace employment is expected to remain strong through 1990. Thousands of jobs should open each year because of the expected increases in defense spending, anticipated increases in research and development funding, demand for commercial transport aircraft, and the need to replace workers who die, retire or transfer to other industries. There will be many opportunities for scientists, engineers and skilled plant personnel.

THE AEROSPACE CHALLENGE

It is the emphasis on research and development that makes the aerospace industry an important source of jobs for technical personnel. Almost 20 percent of all engineers and scientists engaged in R & D in U.S. industries are employed by the aerospace industry.

The pace of innovation and change in aerospace is so great that much equipment becomes obsolete while still in an experimental stage or shortly after being put into production. This means that a continuation and expansion of the United States worldwide superiority in aerospace depends upon important research breakthroughs and their early application to technology and productivity. It means also that the aerospace industry relies heavily on those with maximum scientific, engineering or technical skills.

Ahead in the industry are aircraft that feature aerodynamically improved wings, advanced power plants, new flight control systems, and a host of improvements not yet on the drawing board. In space, the possibility of producing such items as advanced pharmaceuticals, superior crystals for electronics, and stronger, lighter, more temperature-resistant metal alloys presents new opportunities. The aerospace future is exciting. It is also demanding of highly-educated, motivated people to carry on the tradition of innovative technological advances on which aerospace progress depends.

FOR MORE INFORMATION

CONTACT . . .	*. . . YOU CAN OBTAIN*
National Aeronautics and Space Administration, LFC 400 Maryland Avenue, S.W., Washington, D.C. 20546 (202) 453-8393	Information on careers, outlooks and requirements specifically tailored to requests of students and teachers
Federal Aviation Administration Public Inquiry Section (APA-400) Office of Public Affairs 800 Independence Avenue, S.W., Washington, D.C. 20591 (202) 426-8058	"Aviation Career Series," brochures on training, duties and job outlook in aerospace industry
American Institute of Aeronautics & Astronautics Student Programs 1633 Broadway, New York, New York 10019 (212) 408-9727	"Within Your Lifetime—Careers in Aerospace," lists disciplines, requirements ($1/copy)
National Society of Professional Engineers 2029 K Street, N.W., Washington, D.C. 20006 (202) 463-2300	Brochures on engineering careers in aerospace
American Society of Mechanical Engineers 345 E. 47th Street, New York, New York 10017 (212) 644-7722	"A Career for the future,"—booklet on careers in mechanical engineering
University Aviation Association P.O. Box 2321, Auburn, Alabama 36831 (205) 826-4597	Comprehensive book of colleges and universities with aviation programs ($9.95/copy)

SOME WAYS TO GET INVOLVED NOW

Directory of Science Training Programs,Science Service, Inc. 1719 N Street, N.W., Washington, D.C. 20036	Lists institutions conducting science training programs for high-ability junior and senior high school students
"Exploring: The Young Adult Division of the Boy Scouts of America" (Write to the Local Boy Scouts of America Council in your area)	Age 14-20 men and women join aviation posts organized by local industry or business to learn about careers in aviation
NSTA-NASA Space Shuttle Student Involvement Program National Science Teachers Association 1742 Connecticut Avenue, N.W., Washington, D.C. 20009	National contest for 9-12 graders to develop experiments for Shuttle flight; winning proposals are considered for flight on Shuttle mission

Ask your teachers and guidance counselors about other programs and internships they know about

ADDITIONAL RESOURCES

(Available at most libraries)

REFERENCE BOOKS

Occupational Outlook Handbook
Annual Publication of the U.S. Department of Labor

U.S. Industrial Outlook for 200 Industries with Projections for 1984
Publication of the U.S. Department of Commerce

Barron's Profiles of American Universities
Barron's Educational Series

MAGAZINES

AIAA Student Journal, American Institute of Aeronautics and Astronautics, 1633 Broadway, New York, New York 10019.

Aviation Space, Aerospace Education Association, 1910 Association Drive, Reston, Virginia 22091.

Aviation Week & Space Technology, McGraw-Hill Publication, 1221 Avenue of the Americas, New York, New York 10020.

Air Force Magazine, Air Force Association, 1501 Lee Highway, Arlington, Virginia 22209-1198.

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1725 De Sales St., N.W., Washington, D.C. 20036